Technical Article

Do You Have the Correct PFC to Meet the New Standard of Harmonic Current Emissions Standards?

Yuan Tao

Other Parts Discussed in Post: UCC28180

International Electrotechnical Commission (IEC) 61000-3-2: 2014 is a new standard of electromagnetic compatibility (EMC) that supersedes IEC 61000-3-2: 2006 and will be enforced as of June 30, 2017. This part of the standard deals with the limitation of harmonic currents injected into the public supply system. It specifies limits for harmonic components of input current produced by equipment tested under specified conditions and applies to electrical and electronic equipment with input currents as high as 16A per phase connected to public low-voltage distribution systems.

In IEC 61000, in the context of harmonic current limitations, equipment is organized into four classes:

- Class A:
  - Balanced three-phase equipment.
  - Household appliances, excluding equipment identified as Class D.
  - Tools, excluding portable tools.
  - Dimmers for incandescent lamps.
  - Audio equipment.
- Class B:
  - Portable tools.
  - Arc-welding equipment that is not professional equipment.
- Class C:
  - Lighting equipment.
- Class D:
  - Personal computers and personal computer monitors.
  - Television receivers.
  - Refrigerators and freezers with one or more variable-speed drives to control one or more compressor motors.

Unspecified equipment is considered Class A. In all four classes, Class D is the most stringent, because its maximum permissible harmonic current limitation is relevant to its power. In other words, if the equipment works on a low-power level, the maximum permissible harmonic current limitation will be lower. The input currents at harmonic frequencies shall not exceed the values in Figure 1 .

Harmonic order (n)	Maximum permissible harmonic current per watt (mA/W)	Maximum permissible harmonic current (A)
3	3.4	2.3
5	1.9	1.14
7	1.0	0.77
9	0.5	0.4
11	0.35	0.33
13	0.3	0.21
$15 \leq n \leq 39$ (odd harmonics only)	3.85/n	0.15×15/n

Figure 1. Limits for Class D Equipment

In order to meet the requirements of IEC-61000-3-2: 2014, you have to add a power factor correction (PFC) circuit to reduce the input current harmonic. A typical PFC circuit is either passive or active; they're designed for use in different applications with different power levels.

What Is Passive PFC?

The root cause of a poor power factor in a switch-mode power supply is a big capacitor in the DC link after the rectifier diode. The passive PFC generally uses inductor compensation to reduce the phase difference between the fundamental input current and the voltage of the AC input to increase the power factor. But the power factor of a passive PFC is not very high – only 0.7-0.8. And because the inductor is working on the line-switching frequency, you can't avoid audible noise. Figure 2 shows a typical passive PFC circuit.

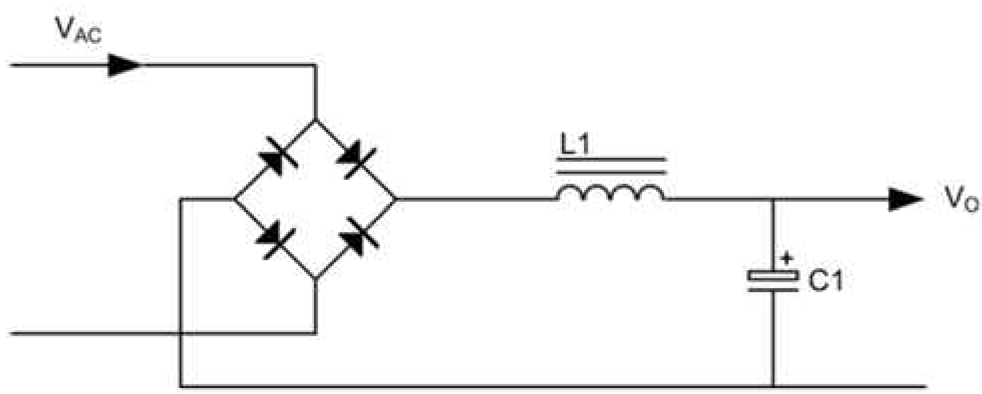

Figure 2. Typical Passive PFC with Inductor Compensation

Figure 3 lists the differences between active and passive PFC.

	Passive PFC	Active PFC
PF	0.6-0.8	>0.99
Total harmonic distortion	20%-30%	<10%
Input voltage range	Low or high line	Universal
Inductor	Large	Small
Output voltage ripple	Big	Small
Electromagnetic interference (EMI) concerns	No	Yes
Cost	Low	Middle
Form factor	Large	Small
Power level	<250W	Any

Figure 3. Comparison between Passive PFC and Active PFC

Transition Mode PFC vs. Continuous Conduction Mode PFC

When the power is more than 250W, the inductor of a passive PFC will be bigger. At this moment, you will usually choose the active PFC. Figure 4 shows a typical active boost PFC circuit.

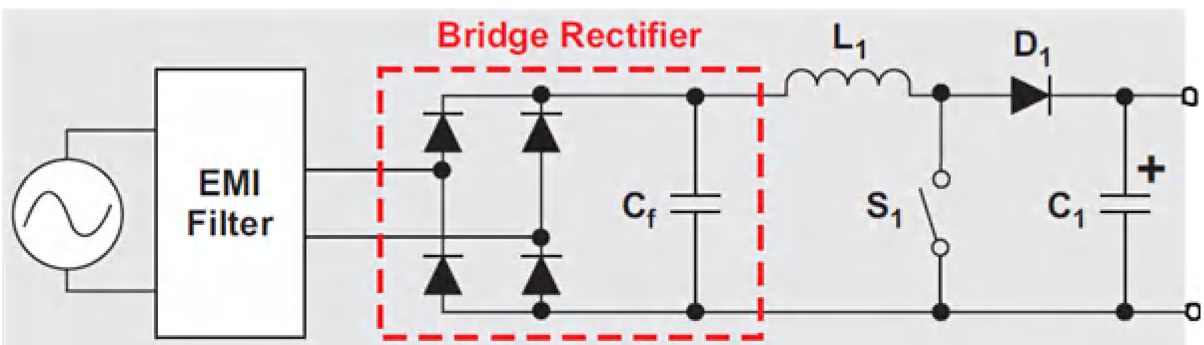

Figure 4. Typical Active Boost PFC

In this topology, if the current of inductor L1 is like Figure 5a, which means that in every switching frequency cycle, the inductor current cross the zero point, known as transition-mode (TM) PFC. If the current of inductor L1 is like Figure 5b, in one line frequency cycle the inductor current will not cross the zero point and work continuously, known as continuous conduction mode (CCM) PFC.

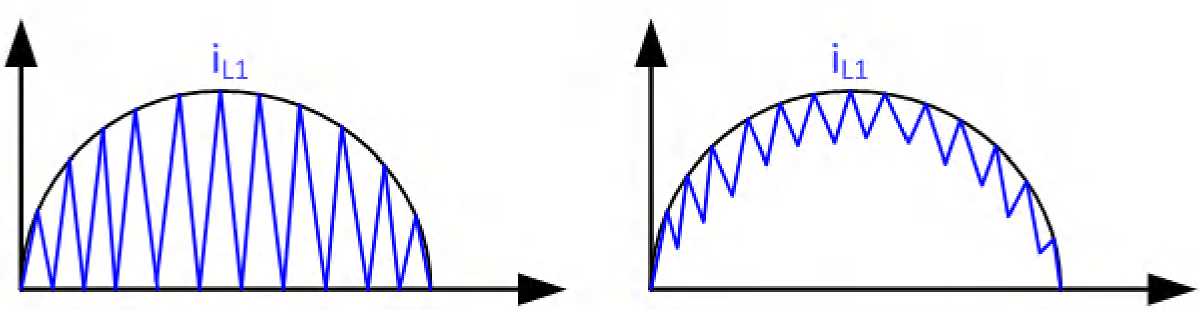

Figure 5. TM PFC (a); Continuous Conduction Mode PFC (b)

From Figure 5, you could conclude that with the same power output, the CCM PFC has the smaller input current ripple. That means that you can get better THD performance. On the other hand, CCM PFC has the smaller root mean square (RMS) current on the PFC choke inductor at the same power. That means that you can get high efficiency because the lower RMS current can reduce the switching loss of S1. But because the inductor current of TM PFC crosses the zero point every switching frequency cycle, there is no recovery loss on the boost diode D1.

The Universal 350W CCM PFC with 98% Efficiency and Small Form Factor Reference Design uses the UCC28180 as the PFC controller, which is a flexible and easy-to-use 8-pin active PFC controller that operates under CCM to achieve high power factor, low current distortion and excellent voltage regulation of boost pre-regulators in AC/DC front ends. The controller is suitable for universal AC input systems operating from 100W to a few kilowatts, with the switching frequency programmable between 18kHz to 250kHz to conveniently support both power metal-oxide semiconductor field-effect transistors (MOSFET) and insulated-gate bipolar transistor (IGBT) switches. An integrated 1.5A and 2A (SRC-SNK) peak gate drive output, clamped internally at 15.2V (typical), enables fast turn-on, turn-off and easy management of the external power switch without the need for buffer circuits. In addition, the controller features reduced current-sense thresholds to facilitate the use of small-value shunt resistors for reduced power dissipation. The UCC28180 need to sense the input AC voltage as the sine reference. This feature helps achieve extremely efficient performance.

Figure 6, Figure 7 and Figure 8 show THD performance at 10%, 60% and full load. From these figures, you can see very good performance even at the 10% load.

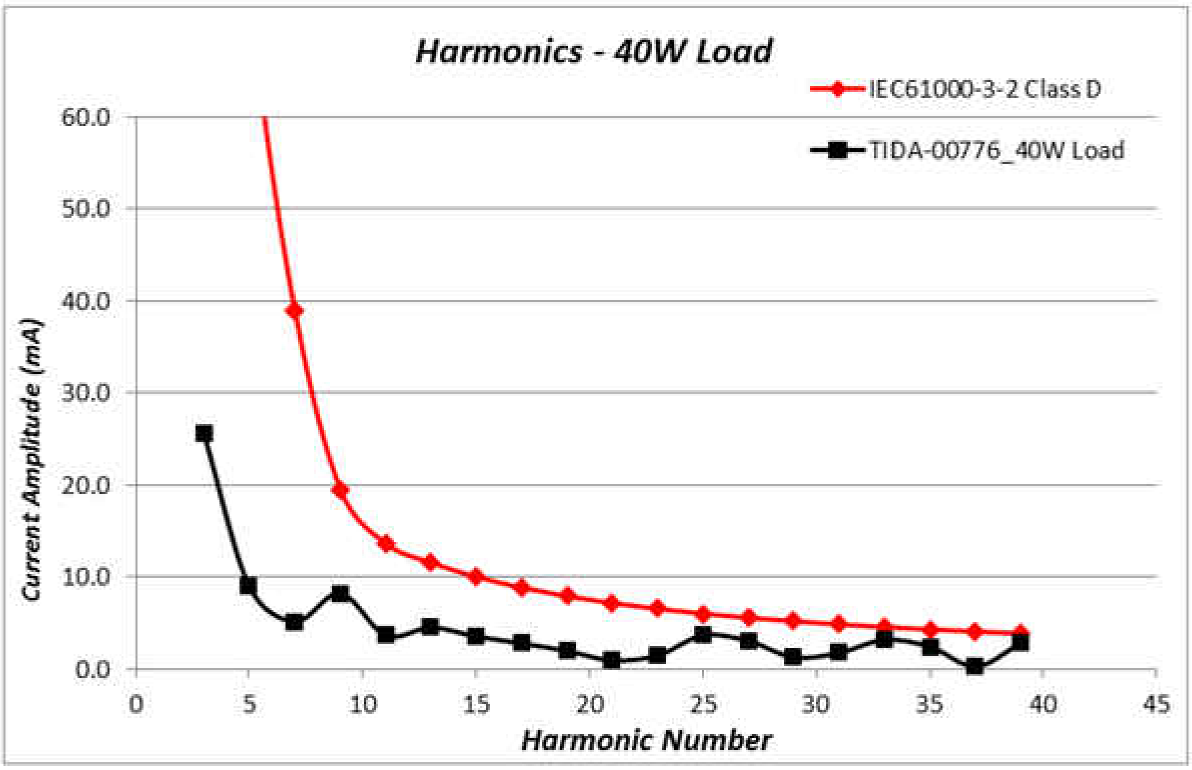

Figure 6. Current Harmonic for 40W Output Power

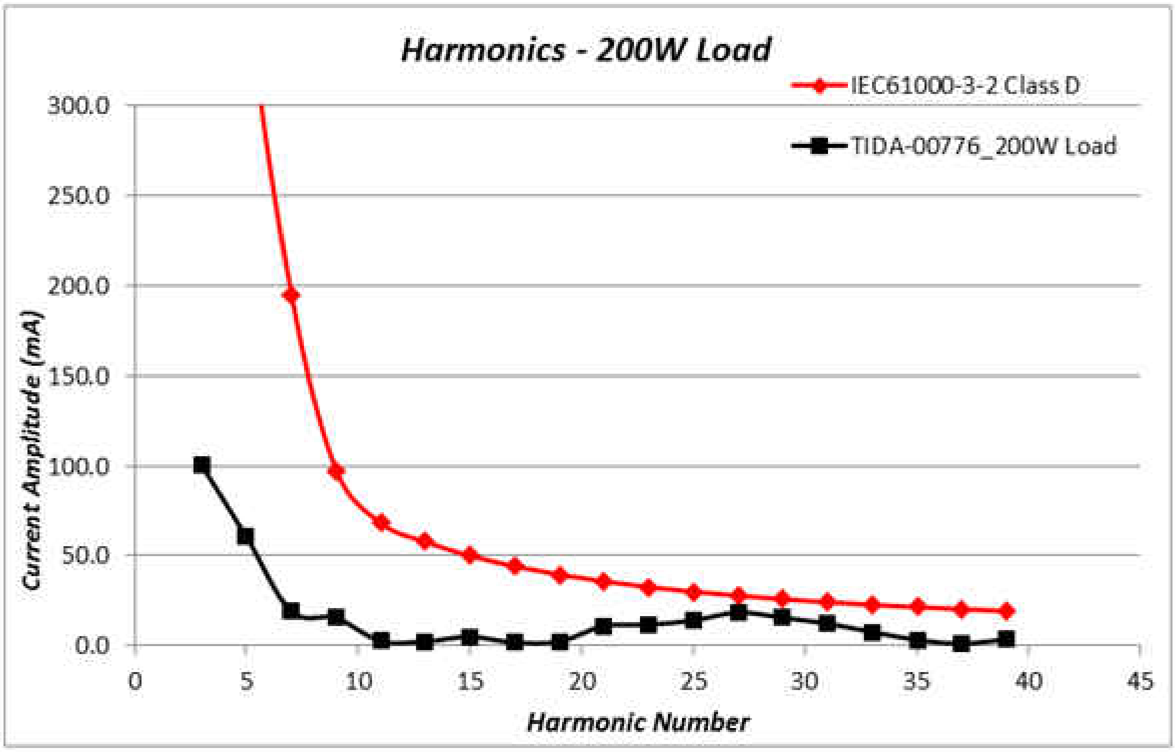

Figure 7. Current Harmonic for 200W Output Power

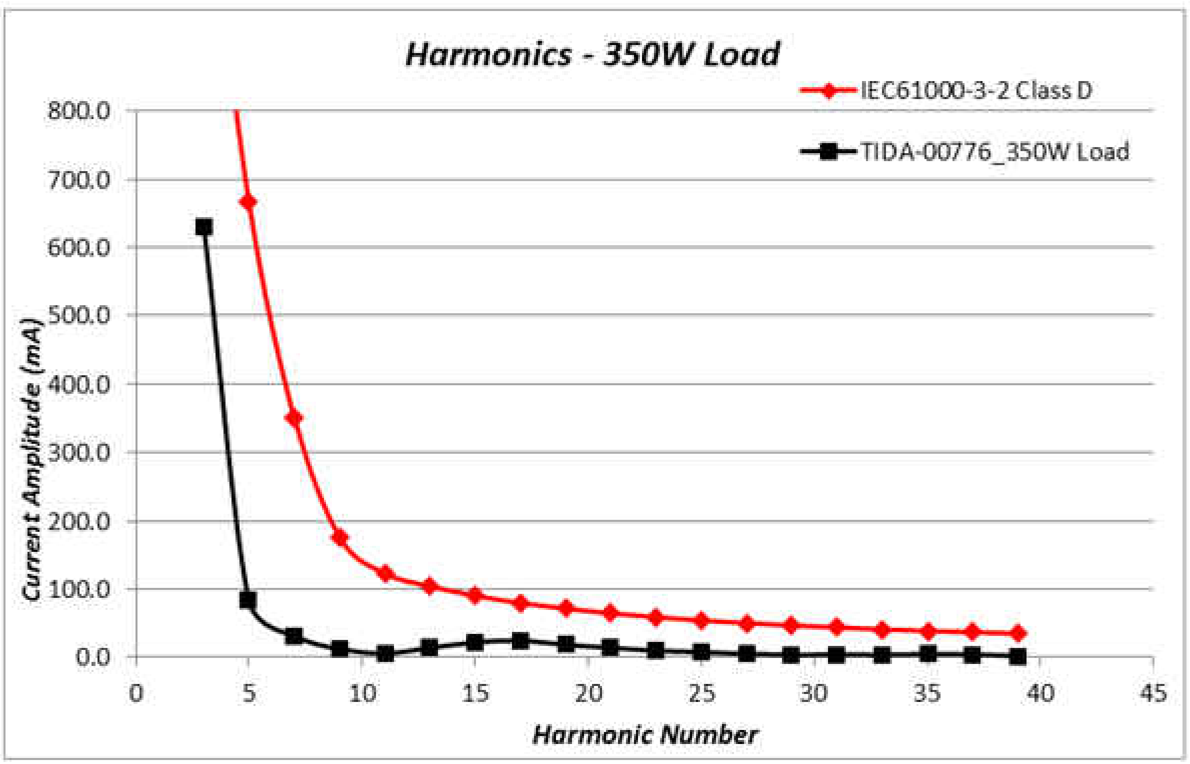

Figure 8. Current Harmonic for 350W Output Power

Per the three figures above, we can find out that even at a very light load, this reference design is still can meet the requirement of Class D in IEC61000-3-2.

Additional Resources

- "Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤16A per phase)."
- Read the Analog Applications Journal article, "Design a transition-mode, bridgeless PFC with a standard PFC controller."

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